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The auxiliary cubic is

$$z^3 - 147{,}000z - 11{,}430{,}000 = 0.$$

Let $z = 200w$, then

$$w^3 - 3.675w - 1.429 = 0.$$

Chart II gives $w = 2.08$, $z = 416$. Chart I gives $b = 92$, $d = 325$, $a = 16.7$ $c = 25.5$, and $x = -8.3 \pm 5i$, $12.8 \pm 13i$. The error in the value of z obtained from the chart may be several units. A good approximation for the correction is easily obtained algebraically. $b + d = 417{,}579$, $bd = 30{,}000$; therefore $b = 325.378$, $d = 92.201$.

$ac = 0 - (b + d) = -417.579$, $a + c = -9$; therefore $a = 16.424$, $c = -25.424$.

In the factored form the equation becomes

$$(x^2 + 16.424x + 92.201)(x^2 - 25.424x + 325.378) = 0.$$

Correct to three places of decimals

$$x = -8.212 \pm 4.976i,\ 12.712 \pm 12.798i.$$

1321, 1471, 1521, 1571, 1621, 1671, 1721, 1771, 1821.

By R. C. ARCHIBALD, Brown University.

1321—Dante Alighieri (born at Florence, 1265) died at Ravenna; his *Divine Comedy* is of mathematical importance for its statement of astronomical notions of the time.

1471—Albrecht Dürer (died, 1528), German painter and engraver, was born at Nürnberg, May 20; he was the author of various works on geometry and perspective, fortification, and human proportion ∗ In his *Zeittafeln zur Geschichte der Mathematik*, Felix Müller states[1] that Indian-Arabic numerals were in this year used for the first time in numbering leaves of a book, in Petrarch's *Liber de remediis utriusque fortunæ*, published by Arnold ther Hoernen of Cologne. This statement is erroneous, in part at least. In the library of the Annmary Brown Memorial, Providence, R. I., there is a copy of Werner Rolewinck's *Sermo in festo præsentationis* . . . ("Sermon preachable on the feast of the presentation of the blessed virgin") issued by the same publisher in 1470. It is paged in Indian-Arabic numerals half way down the right hand margins. In the printed catalogue of this library, prepared by A. W. Pollard of the British Museum, it is stated that *this* was the first printed book with pagination in Indian-Arabic numerals. The work of Petrarch mentioned above may be the *second* work of this kind. The printed catalogues of the British Museum and G. P. Winship's census of incunabula in America do not list a 1471 edition of this work of Petrarch.

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[1] The same statement occurs in F. Unger, *Die Methodik der Praktischen Arithmetik in Historischer Entwickelung*, Leipzig, 1888, p. 16; and in J. Tropfke, *Geschichte der Elementar-Mathematik*, 2. Auflage, Berlin und Leipzig, 1921, p. 26.

unless it is an abridgment by Adrianus the Carthusian that is referred to. This question will elsewhere be discussed in detail by the writer.

1521—First edition of Francesco Ghaligai's *Summa de Arithmetica* published at Florence (compare Riccardi, cols. 499–502) ✳ Second edition of Anton Bartholomeo di Paxi's *Tariffa de Pexi e Mesvre,* published at Venice (first edition, 1503), is of especial interest in the history of commerce ✳ The Cambridge University Press published its first books.

1571—Adriaen Metius (Anthonisz), Dutch mathematician, was born at Metz (whence the name Metius—Cantor), December 9; author of nine minor works on mathematics and astronomy, 1591–1633 (Poggendorff), including *Opera arithmetica et geometrica,* Amsterdam, 1625 ✳ Johann Kepler, noted astronomer and mathematician, was born in Württemberg, December 27 ✳ Jacques Besson, who was professor of mathematics at Orléans about 1570, published, at Galiot du Prè, the little pamphlet *Description et Usaige du Compas Euclidien, contenant la plus-part des Observations qui se font en la Geometrie, Perspective, Astronomie, et Corographie* ✳ First edition published of Leonard Digges's excessively rare *A Geometrical Practise, named Pantometria, divided into three Bookes, Longimetra, Planimetra, and Stereometria, containing Rules manifolde for mensuration of all lines, Superficies, and Solides: with sundry straunge conclusions both by instrument and without, and also by Perspective glasses, to set forth the true description or exact plat of an whole Region: framed by Leonard Digges, lately finished by Thomas Digges his sonne.* . . . De Morgan recorded that in this book he found the earliest printed mention of the word "theodolite." The derivation of this word is unknown, and the derivation sometimes given in connection with corruptions of Arabic words is absurd (*New English Dictionary*). Tycho Brahe regarded Thomas Digges (died, 1595) as one of the greatest geniuses of that time (*Letters illustrative of the Progress of Science in England,* edited by Halliwell, pp. 6, 33.)

1621—Thomas Harriot (born at Oxford, England, 1560), died near Isleworth, July 2; his chief work *Artis analyticæ praxis,*[1] not printed till 1631, was "incomparably the best work on algebra and the theory of equations which had then been published" (Ball, *History of the Study of Mathematics at Cambridge;* but see Cantor, vol. 2, second edition, p. 790) ✳ Claude Gaspar Bachet de Méziriac, French mathematician, especially widely known for his *Problemes Plaisans et delectables* (first edition, 1612, in Harvard University Library), published at Paris his Latin translation, with commentary, of the Greek text of the arithmetic of Diophantus ✳ Johannes Bentz, of Ulm, published at Kempten what he claims to be the first treatise in German on the theory of numbers: *Manuductio ad Numerum Geometricum: Kurtze wol gegründte Anführung zu Erkañdtnuss der Natur vnd Eygenschafften allerhand Arten der figurierten oder geometrischen Zahlen;* . . . ✳ Published at Paris, Denis Henrion's *Collection ou Recueil de divers Traictez Mathematiques, à sçavoir, d'Arithmetique, d'Algebre, de la Solution de divers Problemes et Questions, tant geometriques qu'astronomiques, plusieurs Moyens pour mesurer toutes Sortes de Quantitez* . . . ✳ Published at Hanover, Bartholomæus

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[1] The first printed work to use our ordinary signs for "less than" and "greater than."

Keckermann's *Systema Compendiosum totius Mathematices, hoc est, Geometriæ, Opticæ, Astronomiæ et Geographiæ* . . . ✳ *Prælectiones tresdecim in principivm Elementorvm Evclides, Oxonii habitæ. M.DC.XX* by Sir Henry Savile, published at Oxford; in 1619 Sir Henry founded at Oxford University a chair of geometry, later filled by such men as Briggs, Wallis, Halley, and Sylvester—Hardy is the present incumbent ✳ *Instrument pour construire sur le papier les sections coniques,* by Carlo Ladroni (compare Murhard, *Litteratur der mathematischen Wiss.*, vol. 3, p. 278) was published at Turin.

1671—John Keill, Savilian professor of astronomy at Oxford, 1708–1721, and prominent in the Newton-Leibniz controversy, was born at Edinburgh, December 1. In 1715 he published at Oxford an anonymous work: *Trigonometriæ Planæ & Sphæricæ Elementa item de Natura et Arithmetica Logarithmorum Tractatus brevis* (76 pages) ✳ Albert Curtz, Bavarian Jesuit teacher of philosophy and mathematics, died December 19 ✳ Jan de Witt (1625–1672) published at the Hague a Dutch tract (translated into English, 1852) of interest in the history of insurance[1] ✳ Isaac Newton (1643–1727) wrote his notable memoir "Methodus fluxionum et serierum infinitorum," first published in English translation, by John Colson, in 1736 ✳ Published at London the third part of "one of the classics of mechanics," John Wallis's *Mechanica: sive, de Motu, Tractatus Geometricus. Pars III. in qua, de Vecte, de Axe in Paritrochio, de Trochleâ, de Cochleâ, de Motibus Compositis, de Percussione, de Cuneo,* . . . .

1721—Lorenzo Lorenzini (born, 1652), a pupil of Viviani, died April 24. While in prison, where for political reasons he was confined for twenty years, he wrote the following work, published at Florence in the year of his death: *Exercitatio geometrica: in qua agitur de Dimensioni omnium Conicarum Sectionum, Curvae Parabolicae, Curvæque Superficiei Conoidis Parabolici,* . . . ✳ John Keill (see above) died September 1 ✳ Published at London, the "6th Edition, much inlarg'd," of Henry Philipps's *The Purchaser's Pattern, shewing the true Value of Land or Houses, by Lease or otherwise . . . also Tables of Interest and Rebate at 6 per Cent.; the Measuring of Land, Board, and Timber, and the False Methods us'd by many therein. Also the Art of Gauging much enlarg'd with many other Rules about Weights and Measurès, Tables of the Excise of Beer and Ale, Tables of Accounts, etc., etc.* ✳ Published at London, the third edition of John Hill's *Arithmetick both in Theory and Practice, made Plain and Easie, with Interest and Annuities, Extraction of the Square and Cube Roots, the Tables and Construction of Logarithms, Arithmetical and Geometrical Progression, etc., etc.* In his *Arithmetic Books,* De Morgan refers to this as "a book of much celebrity."

1771—Jean Jacques d'Ortous de Mairan (born, 1678), mathematical physicist and secretary of the French Academy, died February 20 ✳ Joseph Diez Gergonne (died, 1859), founder and editor of *Annales de Mathêmatiques Pures et Appliquées* (July 1810–August 1831), born at Nancy, France, June 19. He was the author of numerous mathematical papers * Jöns Svanberg, for thirty years professor of mathematics at the University of Upsala, was born July 6 * Jean Baptiste Cochet, rector of the University of Paris, died July 8. He was the author of *La clef des Sciences et des beaux-arts, ou la logique* (Paris, 1750), and translator of P. Varignon's *Eléments de Mathématiques* (Paris, 1731)* First paper by John Landen (1719–1790) on elliptic transcendents (published in the *Philosophical Transactions*): "A disquisition concerning certain fluents which are assignable by the arcs of the conic sections; where are investigated some new and useful theorems for computing the fluents" * Notable memoir "De aequationibus quadrato-cubicis disquisitio analytica" by G. Malfatti (1731–1807) published (*Atti di Siena*, vol. 4). Also the year in which Malfatti was appointed professor of mathematics at the University of Ferrara * *Dioptricae pars tertia* by Leonhard Euler (1707–1783), published at Petrograd (reprinted in *Leonhardi Euleri Opera Omnia*, 1912). Second edition of Euler's *Vollständige Anleitung zur Algebra*, Erster teil, published (first edition, 1770; last edition, *Opera Omnia*, 1911) * Published in London, Edward Noble's *The Elements of Linear Perspective, demonstrated by Geometrical Principles; with Introduction, containing so much of the Elements of Geometry as will render the whole Rationale of Perspective intelligible without any previous Mathematical Knowledge* * Published in Madrid, the first edition of Don Jorge Juan's *Examen Maritimo Theórico Práctico, ò Tratado de Mechanica aplicado á la Construccion, Conscimiento y Manejo de les Navios y demas Embarcaciones* (French edition, 1783) * Published at Leipzig, G. H. Bortz's quarto pamphlet, *De Forma Radicum ex Aequationibus Quadraticis ei simili, quam Cubicae per Methodum Cardani obtinent* * Published at Chester, England, Arthur Burns's *Geodæsia Improved; or a New and Correct Method of Surveying made exceedingly easy, with Appendix concerning the practical Methods of measuring Timber, Hay, Marl Pits, Bricklayers and Plaisterers Work* * *Transactions of the American Philosophical Society*, volume 1, published.

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[1] An interesting sketch of "John De Wit" and his work may be found in *The Insurance Cyclopædia being a Dictionary of the definitions of terms . . . a Biographical Summary . . .*, London, volume 2, 1873.

1821—Heinrich Edward Heine (died, 1881), for many years professor of mathematics in the University of Halle, and author of *Handbuch der Kugelfunctionen* (1861; second edition 1881), was born March 15 * Richard Townsend (died, 1884), for fourteen years professor of natural philosophy in Trinity College, Dublin, and author of *Modern Geometry of the Point, Line and Circle* (1863–65; second edition 1878–81), was born April 30 * Prince Baldassare Boncompagni (died, 1894), founder, editor, and publisher of *Bullettino di bibliografia e di storia delle scienze matematiche e fisiche* (Rome, 1868–1887), was born May 10. He was also the editor of numerous mathematical works, and the author of many papers * Noted Russian mathematician, Pafnouty Livovitch Tchébychef (died, 1894), of the University of Petrograd, was born May 14 * August Nagel, professor of geodesy in the Dresden polytechnic school, was born May 17 * Karl Culmann (died, 1881), professor in the Zürich polytechnic school, was born July 10. He has been referred to as the "founder of graphical statics" * Jacob Heinrich Karl Durège (died, 1893), professor in the polytechnic schools of Zürich and Prague, was born July 13. G. E. Fisher and I. J. Schwatt translated into

English the fourth German edition of his *Elements of the Theory of Functions of a Complex Variable* (Philadelphia, 1896) ✳ Anton Winckler (died, 1892), professor of higher mathematics in the polytechnic school of Vienna, was born August 3 ✳ Wilhelm Johann Otto Ligowski (died, 1893), teacher of mathematics in the marine academy and marine school of Kiel, was born August 10. He is the author of *Tafeln der Hyperbelfunctionen und der Kreisfunctionen* (Berlin, 1890), and of *Sammlung fünfstelliger logarithmischer, trigonometrischer und nautischer Tafeln nebst Erklärungen und Formeln der Astronomie* (Kiel, 1873; fourth edition, Berlin, 1900) ✳ The celebrated English mathematician Arthur Cayley (died, 1895) was born August 16. He was a prolific author of mathematical memoirs ✳ The noted German physicist, Hermann Ludwig Ferdinand Helmholtz (died, 1894), was born August 31 ✳ First number of the *Astronomische Nachrichten* published in September ✳ Franz Friedrich Ernst Brünnow (died, 1891), German astronomer, was born November 18. He was director of the observatory at Ann Arbor, Mich., 1854–1864, professor of astronomy at the University of Dublin and astronomer royal for Ireland, 1865–1874 ✳ Astronomical observatory at Cape of Good Hope founded ✳ Samuel Vince, Plumian professor of astronomy and experimental philosophy at Cambridge University, 1796–1821, died. He was the author of several books including *The Elements of Conic Sections* (1781), and *A Treatise on Plane and Spherical Trigonometry* (1800) ✳ *Cours d'analyse de l'Ecole Polytechnique,* prèmiere partie, by A. L. Cauchy (1789–1857), was published; no other part appeared ✳ Published at Rome, Abate Pietro Franchini's *Saggio sulla Storia delle Matematiche, corredato di scelte Notizie Biografiche,* volume 1 ✳ Published at Mainz, second enlarged edition of J. J. I. Hoffmann's *Der Pythagorische Lehrsatz, mit 32 theils bekannten, theils neuen Beweisen versehen* ✳ Published at London, *Elementary Illustrations of the Celestial Mechanics of Laplace,* Part I, by Thomas Young (1773–1829), one of the "most eminent physicists of his time" ✳ Published at Edinburgh, Sir John Leslie's *Geometrical Analysis, and the Geometry of Curve Lines, being volume second of a course of Mathematics, and designed as an Introduction to the Study of Natural Philosophy.* This work was a development of part of *Elements of Geometry, Geometrical Analysis and Plane Trigonometry, with an Appendix, Notes, and Illustrations,* Edinburgh, 1809 (second edition, 1811; French translation, edited by Hachette, 1818) ✳ Published at Haarlem, James Lockhart's *Leerwijze om den Cubik-Wortel uit alle Getallen te trekken.*

SOME ARITHMETIC OPERATIONS WITH TRANSFINITE ORDINALS.

By ALBERT A. BENNETT, University of Texas.

(Read before the Maryland-Virginia-District of Columbia Section of the Mathematical Association of America, December 11, 1920.)

If we write out the first few non-negative integers in order of increasing magnitude, we shall have

$$0, 1, 2, \cdots, (n-1), n.$$